Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **01 AUG 2010**	2. REPORT TYPE **N/A**	3. DATES COVERED **-**
4. TITLE AND SUBTITLE **Half empty or half full?***		5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S) **Batchinsky A. I., Cancio L. C., Buchman T. G.,**		5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **United States Army Institute of Surgical Research, JBSA Fort Sam Houston, TX**		8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSOR/MONITOR'S ACRONYM(S) 11. SPONSOR/MONITOR'S REPORT NUMBER(S)
12. DISTRIBUTION/AVAILABILITY STATEMENT **Approved for public release, distribution unlimited**		
13. SUPPLEMENTARY NOTES		
14. ABSTRACT		
15. SUBJECT TERMS		

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a REPORT	b ABSTRACT	c THIS PAGE			
unclassified	**unclassified**	**unclassified**	**UU**	**12**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

Half empty or half full?*

Logic, anecdote, and data collectively suggest that early detection and prompt intervention in critical illness improve outcomes at lower costs. Process engineering (e.g., standardization and aggregation of interventions into "bundles") has increased care effectiveness. The next step involves transforming critical care from reactive to preemptive practice through recognition of impending collapse.

The excursion of conventional measures, such as traditional vital signs (VS), urine output, and lactate, beyond "normal" ranges is insufficient to predict critical illness. First, such excursions are used to classify established illness. Acute physiology scores depend on those measures such that prediction and occurrence are indistinguishable. Second, they do not distinguish decompensation that requires life-saving interventions (LSIs) from compensated responses; two decades of experience with the systemic inflammatory response syndrome criteria suggest as much. Third, they occur in the absence of pathology: athletes commonly display hyperthermia, tachycardia, tachypnea, relative hypotension, and low urine output.

Thus, the central challenge is not detection of abnormal VS per se but, rather, recognition that altered physiology will overwhelm compensatory mechanisms, require LSIs, and constitute critical care. How can this be accomplished? The first steps were taken more than two decades ago by Glass and Mackey (1). They observed that, contrary to prevailing opinion, normal physiology is not regular but rather variable, and "dynamical diseases" showed loss of variability. Goldberger et al (2) extended this, recognizing that aging and chronic and acute illness shared this physiologic decomplexification. Furthermore, loss of variability seemed to have predictive power, at least on short time scales (3).

Variability measures have been extensively studied in the context of injury. Several groups have shown heart rate variability (HRV) (using conventional moment statistics) and heart rate complexity (HRC) (typically including entropy) to be complementary or superior to standard VS for identification of injury severity, triage, and definition of the need for LSIs (4–8). In one study in 3154 patients, loss of HRC measured by multiscale entropy predicted death days in advance (6). This evidence, although not immediately generalizable, favors proceeding with multicenter prospective trials evaluating the utility of these tools.

In this issue of *Critical Care Medicine*, Rickards et al (9) offer a skeptical view of electrocardiogram-derived metrics to identify patients with seemingly "normal" VS who require LSIs. Two findings worthy of further consideration were: (1) mean values for 13 HRC and HRV metrics calculated from electrocardiograms during transport distinguished 32 patients who received LSIs from 127 who did not; and (2) there was high intrasubject and intersubject variability, poor reproducibility and specificity, and vulnerability of methods for ectopic events (9). The authors then review previous work by others and express caution toward use of HRC and HRV for triage, which represents a change of position for a group that has previously advocated HRV as a prehospital triage tool (5).

A closer look at the study is illuminating. Rickards et al began with 2988 patients from the Trauma Vitals database (10). The authors then culled 159 cases that displayed "normal" VS and injury severity. In other words, they narrowed their focus to the healthiest patients. This is quite different from previous studies and is a focus that the authors justified as a strategy to determine whether the metrics might offer insight into the trajectory of the least overtly ill. Among the 159 patients, 32 received LSIs at various times before, during, or up to 24 hrs after the analyzed electrocardiogram, and 127 did not. Considering the lack of information about LSI timing and the desire to forecast events with unknown time targets, the way Rickards et al chose to downplay their results is intriguing. Finding 1 echoes previous results, which they reference, and is a strong argument in favor of the use of HRV and HRC. Finding 2 is not new and applies more to HRV than to newer HRC metrics. The distinction between the two types of metrics is important. HRV metrics assume periodic regular oscillations, generally reflect the autonomic nervous system, and are susceptible to external stimuli, psychosomatic status, fitness, age, gender, time of day, and breathing rate and frequency. HRC emerged precisely because it is less sensitive to confounders and, applied consistently, allows for comparison of results from different subjects and even species (11, 12).

Artifacts are the bane of physiologic time series. Nevertheless, it is ill-advised to use interpolation for spurious beats as Rickards et al have done here, because even a single manipulated beat may skew results. Alternative approaches evaluate ectopy as a stratifier (13) or analyze 100- to 200-beat ectopy-free sections to obtain a "snapshot" until clean data become available continuously (14).

It is interesting to note that the use of an HRC metric directed attention to five of 32 patients who needed LSIs and whose VS were unremarkable by design (9). The same metric had an 82% negative predictive value compared to the human caregiver (80%) in the non-LSI group. There are few tools in critical care that have a 16% yield predicting the need for LSIs in seemingly healthy patients. Do we really want to neglect an alert that comes at trivial signal-processing cost?

How should the critical care community view the Rickards et al take on the utility of altered physiologic variability as a clue to impending decompensation? Those with the "glass half-empty" perspective will discard these metrics and look elsewhere. Those with the "glass half-full" perspective will point to the success of previous studies and evaluate

*See also p. 1666.

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The authors have not disclosed any potential conflicts of interest.

DOI: 10.1097/CCM.0b013e3181e94230

the methods at the bedside. Such half-empty/half-full disputes are distractions. Single-sensor paradigms will always be outperformed by multivariate analysis. Multivariate assessment of methodologically different descriptors via machine learning may be the optimal way forward (8). Efforts are already underway to perform continuous analysis of electrocardiography with automatic signal-quality verification. This and other advanced technologies will permit evaluation of changes in patient status over time and reveal responsiveness of physiology to treatment.

Lumping conceptually and methodologically different tools such as variability and complexity (and, soon, modularity) and discouraging their use simply because one tool functions suboptimally at an extraordinarily difficult task does a disservice to the emerging field of complexity science and its application to critical care (15). As long as "what is in the glass" seems to complement other data in most situations, the half-empty/half-full discussion is moot.

Andriy I. Batchinsky, MD
Leopoldo C. Cancio, MD, FACS
COL, MC, U.S. Army
U.S. Army Institute of Surgical Research
Fort Sam Houston, TX
Timothy G. Buchman, PhD, MD
Emory Center for Critical Care
Atlanta, GA

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Communication of sedation in the intensive care unit: Is it the real issue?*

Mirski et al (1) deserve appreciation for their attempt to develop and validate a new instrument to facilitate communication of sedation in intensive care unit patients. The authors address an important issue in intensive care. Most health professionals face the challenge of assessing level of sedation, documenting, and communicating the scores for appropriate management. Mirski et al (1) report on the validity and reliability of the Nursing Instrument for the Communication of Sedation (NICS). This new instrument is intended for nurses, as indicated in its name, and aims to facilitate communication of sedation level.

The authors (1) make a case for using an intuitive scoring system, "based on the intuitive rhetorical metric of 'threes' (good-better-best)," in a linear construct (0, optimal state of sedation; −1 or +1, near-optimal state; −2 or 2, nonthreatening state of sedation but requiring intervention; and −3 or 3, threatening condition requiring immediate attention). This type of scoring was used earlier by Curley et al (2) for the construction of the State Behavioral Scale, which proved to be easy to use in comparison with summative scores, logical (in the use of negative scores for sedation, positive scores for agitation, and a zero score for neither sedation nor agitation), and easy to recall. Curley et al (2) defined the State Behavioral Scale as a two-dimensional scale: sedation and agitation. What is somewhat disappointing in the article by Mirski et al (1) is the lack of information on the conceptualization of the NICS, which is an inherent part of the process of validation of a new instrument (3). According to the Herr et al

*See also p. 1674.
Key Words: sedation; critical care; psychometrics; instrument development
The author has not disclosed any potential conflicts of interest.

DOI: 10.1097/CCM.0b013e3181e94220